Effect of dietary lipid on fatty acid composition of the muscle of reared Tunisian greater amberjack *Seriola dumerili*

by

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ABSTRACT. - The greater amberjack *Seriola dumerili* (Risso, 1810) is one of the most commercially important seawater fish species in Tunisia. The aim of this study was to determine the best rate of dietary lipid for *Seriola dumerili* during the refining period and its effect on muscle fatty acid composition. Two groups of fish were fed for 8 weeks with commercial diets with increasing lipid levels (45% crude protein, 17 or 25% lipid). The fat content and fatty acid composition of edible muscle were investigated. The lipid content increased with increasing dietary lipid levels. Fatty acid (FA) composition of the muscle reflected dietary FA profiles. Along the experiment, polyunsaturated fatty acid (PUFA) levels of *Seriola dumerili* were found to be higher than those of saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA) for the two diets tested. The proportions of n-3 PUFAs of *Seriola dumerili* (ranging from 19.24 ± 0.98% to 29.15 ± 0.49% and 33.89 ± 0.94% for fish fed the 17% fat diet and the 25% fat diet, respectively) were higher than those of n-6 PUFAs. Docosahexaenoic acid (DHA 22:6 n-3), eicosapentaenoic acid (EPA 20:5 n-3) and arachidonic acid (AA 20:4 n-6) were the main PUFA. Farmed *Seriola dumerili* was characterised by a higher n-3/n-6 ratio in different samples studied and diet tested, but the best ratio was observed with the lipid rich diet at 45 days of refining. Greater amberjack provides the consumer with a high proportion of n-3 FA, particularly DHA and EPA.

RÉSUMÉ. - Effet des lipides alimentaires sur le profil en acides gras du muscle de la sériole *Seriola dumerili* en élevage.

Le but de cette étude est la détermination du meilleur taux de lipides alimentaires pour la sériole *Seriola dumerili* (Risso, 1810) pendant la période d'affinage et son effet sur la composition en acides gras de sa chair, cette espèce ayant une haute valeur commerciale et nutritionnelle en Tunisie. Deux groupes de poissons ont été nourris pendant 8 semaines avec deux aliments commerciaux ayant des teneurs différentes en lipides (45% de protéines, 17 ou 25% de lipides). Les lipides totaux ont été dosés et le profil en acides gras de ces sérioles a été déterminé. La teneur en lipides totaux a augmenté avec l'aliment riche en lipides (25%). Le profil en acides gras reflète celui de l'aliment utilisé. Les acides gras polyinsaturés (AGPI) sont plus abondants que les acides gras saturés (AGS) et les acides gras monoinsaturés (AGMI) pour tous les échantillons et avec les deux aliments. Les AGPI de la famille n-3 (allant de 19,24 ± 0,98% au début de l'affinage jusqu'à 29,15 ± 0,49% pour l'aliment 17% et 33,89 ± 0,94% pour l'aliment 25%) sont plus abondants que les AGPI de la famille n-6. L'acide docosahexaénoique (DHA, 22 : 6 n-3), l'acide écosapentaénoique (EPA, 20 : 5 n-3) et l'acide arachidonique (AA, 20 : 4 n-6) sont les AGPI majeurs. La sériole d'élevage est caractérisée par un rapport n-3/n-6 important, la valeur maximale est observée au 45e jour de l'expérience avec l'aliment à 25% de lipides. *Seriola dumerili* représente une source importante d'AGPI, notamment ceux de la série n-3 à longue chaîne DHA et EPA.

Key words. - Carangidae **-** *Seriola dumerili* - Fatty acids - PUFA - Dietary lipid - n-3/n-6 ratio.

Lipids are important components in the human diet. The lipids of marine fish species are generally characterized by low levels of linoleic acid (18:2n-6) and linolenic acid (18:3n-3) and high levels of long-chain n-3 polyunsaturated fatty acids (Steffens, 1997). Among the polyunsaturated fatty acids, eicosapentaenoic acid (EPA, C20:5n-3) and docosahexaenoic acid (DHA, C22:6n-3) are the dominant n-3 fatty acids in marine fish (Ackman, 1989). These fatty acids are of great importance to humans for the prevention of the coronary artery disease (Conner, 2000; Mozaffarian *et al*., 2005). Since DHA is a major component of the brain, eye retina and heart muscle, DHA has been considered as important for brain and eye development and also for good cardiovascular health (Ward and Singh, 2005). EPA has also been reported to be useful treating in brain disorders and cancer (Fenton *et al*., 2000). Fish lipids are a good source of EPA and DHA. However, for pregnant and nursing mothers it is recommended that EPA content should be low because it causes bleeding (Ward and Singh, 2005). The western diet contains high levels of omega-6 and low levels of C18 n-3 PUFAs which is considered to be an unbalanced diet. Populations which consume 0.5-0.7 g/day DHA have a lower incidence of heart disease. The general recommendation for daily intakes of DHA/EPA is 0.5 g for infants and 1 g/day for adults and patients with heart diseases (Kris-Etherton *et al*., 2002).

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Greater amberjack *Seriola dumerili* is a marine pelagic fish species with a circumglobal distribution throughout warm and tropical waters (Ochiai and Tanaka, 1986; Thompson *et al*., 1999). This species has been targeted for aquaculture in Japan and the Mediterranean region because of its high growth rate, excellent flesh quality and high commercial value (Masuma et *al*., 1990; Tachihara *et al*., 1993; Mazzola *et al*., 2000; Mylonas *et al*., 2004; Papandroulakis *et al*., 2005; Jerez *et al*., 2006; Mushiake, 2006; Takakuwa *et al*., 2006). The aquaculture of this species began in the 1960s in Japan and relied on wild juveniles caught around southern Japan for seed (Takaoka, 2005).

Although some information has been published concerning the nutrient requirement for *Seriola dumerili* (Kent et *al*., 2001; López *et al*., 2004, 2006), basic studies concerning its nutritional requirements are still lacking. It is well known that marine carnivorous fish preferentially use protein as an energy source but lipids are a source of dietary energy and essential fatty acids (EFA) and can spare protein in the diet of many fish species (Wang *et al*., 2005; Martins *et al*., 2007; Schuchardt *et al*., 2008). Within certain limits, increasing the dietary lipid level has been shown to improve the feed efficiency of marine fish species (Cho *et al*., 2005; Du *et al*., 2005).

Studies have indicated that diets with including lipid (over 22%, provided by fish oil) produce poorer performance in *Seriola dumerili* than diets with lower lipid levels 15 to 18%, (López et *al*., 2006). Many studies have analysed the effects of dietary lipid level on growth performance and body composition in marine fish, like European sea bass (Peres and Oliva-Teles, 1999), red sea bream and Japanese yellowtail (Oku and Yogata, 2000), haddock (Nanton *et al*., 2001), grouper (Luo *et al*., 2005), cobia (Wang *et al*., 2005) and Atlantic halibut (Martins *et al*., 2007). Although the dietary FA profile is generally reflected in fish tissue, the influence of dietary lipid level on *Seriola dumerili* FA profiles has not been studied.

Thus, the aim of the present study was to evaluate the effects of varied levels of dietary lipid on body lipid composition and FA profile of *Seriola dumerili* muscle.

MATERIAL AND METHODS

A group of young amberjack *Seriola dumerili* indoors having an initial weight ranging from 100 to 150g was caught at the Tunisian Mediterranean coast in July 2003.

The period of acclimatization lasted from August to November 2003; fish were divided in three groups. Each group was fed with an experimental diet: A1 (cool fish, *Sardina pilchardus*), A2 (semi-dry pellets) and A3 (dry pellets; standard diets 17% diet). Fish fed with the A3 diet showed the best captivity adaptation. The final mean weight was 432 ± 53 g. The fatty acid profile of *Seriola dumerili* at the end of the acclimatization is reported in table I.

Table I. - Fatty acids composition (% of total fatty acids) in fillets of farmed *Seriola dumerili* (n = 5) at the end of the acclimatization period. Each fatty acid is presented as a percentage of the total. SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA n-3: n-3 polyunsaturated fatty acids; PUFA n-6: n-6 polyunsaturated fatty acids; PUFA: polyunsaturated fatty acids; EPA: eicosapentaenoic acid; DHA: docosahexaenoic acid.

Fatty acid	Initial composition
C14:0	4.61 ± 0.76
C16:0	13.3 ± 1.86
C17:0	2.01 ± 0.14
C18:0	3.09 ± 0.33
C20:0	0.28 ± 0.11
C22:0	2.31 ± 0.43
C24:0	0.81 ± 0.23
Total SFA	26.41 ± 1.78
C14:1 n-5	0.23 ± 0.05
C16:1 n-7	4.79 ± 0.98
C18:1 n-7	15.31 ± 1.32
C18:1 n-9	3.64 ± 0.65
C20:1 n-9	2.76 ± 0.98
C22:1 n-9	0.76 ± 0.12
C24:1 n-9	0.310.09
Total MUFA	27.80 ± 1.09
C18:2 n-6	12.38 ± 2.43
C20:2 n-6	0.98 ± 0.34
C20:3 n-6	0.12 ± 0.09
C20:4 n-6	3.73 ± 0.98
C22:4 n-6	0.06 ± 0.03
Total PUFA n- 6	17.27 ± 1.99
C18:3 n-3	2.68 ± 0.87
C20:5 n-3 (EPA)	2.37 ± 0.57
C22:5 n-3	0.15 ± 0.06
C22:6 n-3 (DHA)	9.31 ± 1.09
Total PUFA n- 3	14.51 ± 1.32
Total PUFA	31.78 ± 2.98
n- 3/PUFA	0.46 ± 0.11
n-3/n-6	0.84 ± 0.21

Then, fish were reared for 9 months (December 2003 to August 2004) with a standard commercial diet containing 45% protein and 17% lipid. The final mean weight was 1229 ± 47 g.

At this stage, the refining experience started and the fish were divided into 2 different groups for each diet, 45 fish in each group. The initial weight in the first group fed with the standard diet (17% lipid and 45% protein) was 1251 ± 32,3 g and 1203 ± 45,9 g for the second group eating the rich diet (25% lipid and 45% protein). The experimental period lasted 60 days (from September to October 2004), and this period is considered to be the favourite period for flesh refining of

Table II. - Lipid content (g lipid/100 g dry weight) determined in each sample for fillets of *Seriola dumerili* fed with the 17% and 25% lipid diets, during the refining period (day 0 to day 60). (n = 5). [a]: differences between the two diets.

	d0	d15	d30	d45	d60	Signification	
Diet 17%	24.64 ± 2.00	25.38 ± 0.33	23.36 ± 1.42	25.36 ± 0.61	37.67 ± 0.8	***	ns[a]
Diet 25%		26.08 ± 0.35	24.80 ± 1.00	26.00 ± 1.20	39.37 ± 1.61	***	

Seriola dumerili under culture conditions in our area.

The two commercial diets ((Ecolife, Biomar) contained the same protein level (45% CP) but two different lipid levels (17% and 25%). The pellet diameter was 5 mm for the 17% and 3.5 mm for the 25% lipid diet. Fish were fed by hand three times a day (09:00, 13:00 and 17:00) to apparent satiation. Pellets were distributed slowly permitting all fish to eat. Unconsumed food was removed automatically with outgoing water.

Five fish per tank were sampled every 15 days to determine muscle composition. After anaesthesia with phenoxyethanol at a concentration of 0.3 ml/l, fish were weighed, measured and processed. For each fish sampled, the edible portion was mixed, ground and remixed to obtain a single homogeneous composite sample of the product. More precisely, the edible portion for fish was defined as fillets i.e., flesh without skin and without entrails, being lyophilised.

Lipids were extracted with dichloromethane/ methanol (2:1) according to Folch *et al.,* (1957) and expressed as g/100g dry weight (DW). Fatty acids were methylated with BF_3 in methanol. The fatty acids methyl esters were recovered with hexane (Metcalfe *et al*., 1966) and analysed by capillary gas chromatography (column: 30 m x 0.25 mm HP-Innowax; flame ionization detect temperature at 280°C; carrier gas N_2 at 1 ml/min; injector temperature 250°C; oven temperature programmed from 180 to 250°C) using a Hewlett-Packard HP 5890 capillary gas chromatograph linked to an HP Chemstation integrator.

The identification of fatty acid methyl esters was performed by external standards (all purchased from Sigma Chemical Co) submitted to the same processes of manipulation as the biological samples analysed. The values of fatty acids were presented as area under the curve percentage of total fatty acids.

Data were reported as mean ± SD (standard deviation) and analyzed by one way of variance analysis (ANOVA) to determine differences between means at 5% confidence level. Significant differences ($p < 0.05$) among mean were determined by Duncan multiple range test using the Duncan *post hoc* test. All statistical analyses were performed using SPSS v.16.0 for Windows. Statistical differences are presented by asterisks) (***: $p < 0.001$; **: $p < 0.01$, *: $p < 0.05$). a, b and ab indicate that it is in favour of the 17% or 25% or the two diets (a: in favour of 17% diet, b: in favour of 25% diet and ab: observed with the two diets).

RESULTS

The fish have grown substantially in the mean time attaining a mean weight of 1734 ± 63 g for the standard diet and 1767 ± 44,01 g for the second.

The effect of dietary lipid on muscle fat is presented in table II. The lipid content of the whole muscle increased with dietary lipid along the refining period in each group of fish and achieved the highest level at the end of experiment with the two diets tested, 37.67 ± 0.8 g/100g DW for 17% fat diet and 39.37 ± 1.61 g/100g DW for 25% one. Significant differences ($p < 0.05$) were observed along the 8 weeks in each diet. However, the dietary lipid level had no significant effect on lipid content.

The fatty acid composition of the commercial diets is presented in table III. To sum up, the fatty acids 16:0, 16:1 n-7, 18:1 n-9, 18:2 n-6, 20:4 n-6, 20:5 n-3 and 22:6 n-3 were the most abundant of the saturated, mono and polyunsaturated fatty acids. In addition to the fatty acids listed above, the 17% fat diet was very high in 14:0, 18:1 n-9, 18:2 n-6 and had the lowest n-3/n-6 ratio (Tab. III). The 25% fat diet was higher in 20:4 n-6, 20:5 n-3 and 22:6 n-3, the n-3/n-6 ratio was 1.67.

The fatty acids profile of the total lipid of muscle tissue is shown in table IV. The major fatty acids identified in *Seriola dumerili* were 16:0 (palmitic), 16:1 n-7 (palmitoleic), 18:1 n-9 (oleic), 18:2 n-6 (linoleic), 20:4 n-6 (arachidonic AA), 20:5 n-3 (eicosapentaenoic acid EPA) and 22:6 n-3 (docosahexaenoic acid DHA) in all samples.

Palmitic acid was the primary saturated fatty acid (SFA), it decreased as dietary lipid increase. At the end of experiment (day 60), its value was 15.69 ± 0.44% for the 25% fat diet. But for the 17% fat diet, the palmitic acid increased and the higher level 19.05 ± 0.32% was observed at 45 days of refining.

SFA were maintained almost stable along the experiment. Their amount ranged from 32.29 ± 0.84% to 31.54 ± 0.50% for fish fed the 17% fat diet. An insignificant decrease was observed (32.29 ± 0.84% to 29.25 ± 0.50%) for the 25% diet on day 60. MUFA decreased significantly along the experiment. Oleic acid was identified as a primary MUFA in *Seriola dumerili* for all samples. A significant reduction ($p < 0.001$) was observed in the oleic acid (C18:1 n-9) in account of the 25% fat diet compared to 17% diet; for instance after 60 days the amount was 9.87 ± 0.2% versus

Table III. - Composition of dietary fatty acids, the 17% and 25% lipid diets (% of total fatty acid). SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA n-3: n-3 polyunsaturated fatty acids; PUFA n-6: n-6 polyunsaturated fatty acids; PUFA: polyunsaturated fatty acids; EPA: eicosapentaenoic acid; DHA: docosahexaenoic acid.

Fatty acids	Diet 17%	Diet 25%
C14:0	5.04	0.1
C14:1	0.10	0.01
C16:0	16.19	16.00
C16:1 n-7	5.22	7.23
C17:0	1.01	1.32
C18:0	2.99	3.18
C18:1 n-9	16.01	13.80
C18:1 n-7	2.02	3.80
C18:2 n-6	16.80	7.52
C18:3 n-3	2.95	2.01
C20:0	0.10	0.01
C20:1 n-9	2.08	2.50
C20:2 n-6	0.23	0.33
C20:3 n-6	0.05	0.01
C20:4 n-6	4.53	6.59
C20:5 n-3 (EPA)	6.37	8.87
C22:0	5.71	8.65
C22:4 n-6	0.12	0.38
C22:1	0.36	0.74
C22:5 n-3	0.22	0.33
C24:0	1.02	1.89
C22:6 n-3 (DHA)	10.38	13.58
C24:1	0.52	0.95
SFA	32.06	31.15
MUFA	26.31	29.03
PUFA	41.65	39.62
PUFA n-3	19.92	24.79
PUFA n-6	21.73	14.83
n-3/n-6	0.92	1.67

10.53 ± 0.28% (Fig. 1). These results coordinate with the content of the feed used (Tab. III). Palimitoleic acid was the second most abundant MUFA (maximal and minimal values 2.96 ± 0.38% and 5.37 ± 0.16%, respectively).

The PUFA content of muscle of greater amberjack ranged from 37.22 ± 0.14% to 48.24 ± 0.56% for fish fed the 17% lipid level diet and 49.60 ± 0.92% for fishes fed the 25% fat diet. In this work, the PUFA content was generally much higher than the SFA and MUFA, and increased significantly ($p < 0.01$) in favour of the 25% fat diet.

The FAs 18:2 n-6 and 20:4 n-6 were the most abundant of the n-6 PUFA. It has been reported to range from 10.59 ± 0.21 to 15.76 ± 0.91% and from 2.12 ± 0.13 to 4.30 ± 0.30% of total fatty acids respectively. AA decreases with time from 4.11 ± 0.12 to 2.49 ± 0.20 with diet 17% and 3.30 ± 0.34% with diet 25%. As shown in table IV, a noticeable decrease was observed with diet 17% along the refining period but a slight decrease with diet 25% especially beyond 30 days: 3.16- 3.20- 3.30% of total fatty acids.

Tunisian greater amberjack showed high concentration of EPA and DHA, which were the major n-3 PUFA. The level of DHA ranged between 11.40 ± 0.43 to 21.68 ± 0.80, this level increased the n-3 PUFA content for the two tested diets. The significant difference ($p < 0.01$) was in favour of the 25% fat diet, which had the higher DHA amount (13.58%). DHA was the highest in samples from the rich diet and the higher value was obtained after 45 days: (22.80 ± 0.63% (Fig. 1). At the same time, in samples from the 17% diet, DHA value was only 20.48 ± 0.66%. The difference was significant ($p < 0.05$). But at day 60, we note a drop in DHA amount for the diet tested and the difference was significant ($p < 0.01$) (Tab. IV) and (Fig. 1). PUFA n-3 increase along the experiment with both diets with higher final proportion in fish fed the 25% lipids diet (from 19.24 ± 0.98 to 29.15 ± 0.49 and 33.89 ± 0.94 respectively)

The ratio of n-3 PUFAs/n-6 PUFAs in total lipid of *Seriola dumerili* changed mostly from 1.06 ± 0.11 to 2.27 ± 0.06. The high level was observed at day 45 in samples from rich diet (Tab. IV), differences were significant ($p < 0.01$). A

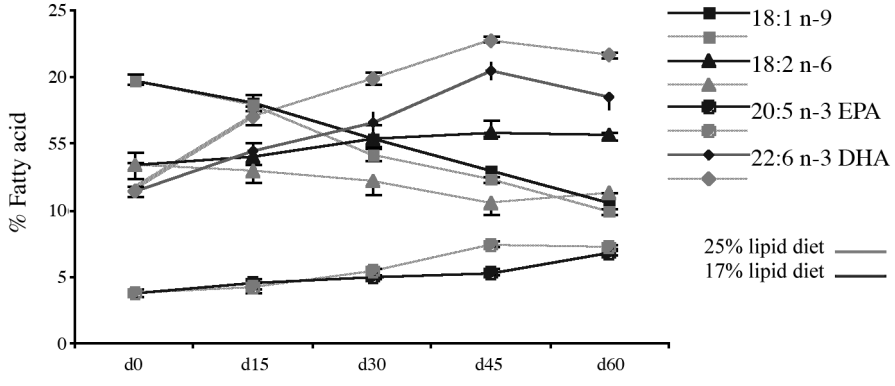

Figure 1. - Variation of interesting fatty acids along the experiment with the two diets.

Table IV. - Fatty acid composition of fish fillets (% total fatty acid methyl esters) during the duration of the experiment with the 17% and 25% lipid diets. (n = 5). Each fatty acid is presented as a percentage of the total, values reported are means ± SD;*($p < 0.05$), **($p < 0.01$), ***($p < 0.001$), ns = $p > 0.05$. a: in favour of the 17% fatty lipid; b: in favour of the 25% fatty lipid; ab: observed with the two diets. SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA n-3: n-3 polyunsaturated fatty acids; PUFA n-6: n-6 polyunsaturated fatty acids; PUFA: polyunsaturated fatty acids; EPA: eicosapentaenoic acid; DHA: docosahexaenoic acid.

Fatty acid	Initial	d15		d 30		d 45		d 60		
	T0	Diet 17%	Diet 25%	Diet 17%	Diet 25%	Diet 17%	Diet 25%	Diet 17%	Diet 25%	sign
C14:0	4.00 ± 0.24	3.79 ± 0.14	3.54 ± 0.13	1.95 ± 0.20	2.08 ± 0.10	1.28 ± 0.07	1.75 ± 0.5	1.95 ± 0.07	2.04 ± 0.31	***b
C16:0	18.41 ± 0.40	17.10 ± 0.45	17.02 ± 0.47	17.07 ± 0.58	18.10 ± 0.50	19.05 ± 0.32	18.29 ± 0.18	19.01 ± 0.36	15.69 ± 0.44	**a
C18:0	5.06 ± 0.27	4.89 ± 0.31	4.89 ± 0.27	5.46 ± 0.18	6.27 ± 0.20	7.20 ± 0.08	5.84 ± 0.30	5.79 ± 0.49	6.38 ± 0.27	**a
C20:0	0.58 ± 0.14	1.01 ± 0.09	0.94 ± 0.10	0.87 ± 0.06	0.89 ± 0.04	0.61 ± 0.04	0.81 ± 0.05	0.99 ± 0.03	0.79 ± 0.18	*a
C22:0	2.70 ± 0.87	4.49 ± 0.41	4.16 ± 0.40	3.05 ± 0.39	2.37 ± 0.27	1.65 ± 0.16	2.34 ± 0.16	1.55 ± 0.03	1.90 ± 0.65	**b
C24:0	0.80 ± 0.18	1.36 ± 0.10	1.37 ± 0.06	2.37 ± 0.27	1.97 ± 0.42	1.34 ± 0.05	1.59 ± 0.03	1.26 ± 0.04	1.87 ± 0.43	*b
Total SFA	32.29 ± 0.84	31.62 ± 1.36	32.97 ± 0.71	32.07 ± 1.43	33.16 ± 0.93	32.32 ± 0.57	32.05 ± 0.26	31.54 ± 0.50	29.25 ± 0.50	ns
C14:1 n-5	0.70 ± 0.17	0.60 ± 0.14	0.25 ± 0.14	0.40 ± 0.15	0.15 ± 0.02	0.30 ± 0.11	0.52 ± 0.13	0.04 ± 0.02	0.42 ± 0.18	*a
C16:1 n-7	5.37 ± 0.16	5.21 ± 0.17	4.74 ± 0.28	2.96 ± 0.38	3.76 ± 0.30	3.30 ± 0.52	4.08 ± 0.04	4.69 ± 0.34	4.96 ± 0.24	**b
C18:1 n-7	3.66 ± 0.48	2.58 ± 0.12	2.63 ± 0.02	2.69 ± 0.17	2.89 ± 0.08	2.80 ± 0.19	2.96 ± 0.1	4.01 ± 0.37	3.60 ± 0.5	*b
C18:1 n-9	19.80 ± 0.36	18.03 ± 0.57	17.97 ± 0.78	15.37 ± 0.48	14.19 ± 0.45	12.93 ± 0.23	12.34 ± 0.23	10.53 ± 0.28	9.87 ± 0.2	**a
C20:1 n-9	0.40 ± 0.25	0.35 ± 0.20	0.28 ± 0.18	0.11 ± 0.01	0.07 ± 0.02	0.26 ± 0.06	0.03 ± 0.01	0.02 ± 0.07	0.92 ± 0.26	*b
C22:1 n-9	0.19 ± 0.08	0.67 ± 0.37	0.12 ± 0.05	1.43 ± 0.67	0.43 ± 0.12	0.29 ± 0.04	0.35 ± 0.09	0.64 ± 0.18	0.79 ± 0.16	*b
C24:1 n-9	0.37 ± 0.12	0.36 ± 0.04	0.53 ± 0.30	0.42 ± 0.15	0.39 ± 0.11	0.38 ± 0.15	0.16 ± 0.07	0.29 ± 0.06	0.61 ± 0.21	ns
Total MUFA	30.49 ± 0.85	27.8 ± 0.32	26.52 ± 0.97	23.38 ± 0.28	21.88 ± 0.98	20.26 ± 087	20.44 ± 0.10	20.22 ± 0.43	21.17 ± 0.49	***a
C18:2 n-6	13.34 ± 1.02	13.96 ± 1.04	13.02 ± 0.60	15.37 ± 1.00	12.15 ± 0.60	15.76 ± 0.91	10.59 ± 0.21	15.62 ± 0.11	11.37 ± 0.38	**a
C20:2 n-6	0.35 ± 0.09	0.19 ± 0.03	0.23 ± 0.04	0.33 ± 0.08	0.40 ± 0.11	0.11 ± 0.01	0.12 ± 0.01	0.33 ± 0.15	0.14 ± 0.02	ns
C20:3 n-6	0.28 ± 0.07	0.36 ± 0.02	0.13 ± 0.07	0.38 ± 0.07	0.27 ± 0.08	0.43 ± 0.22	0.12 ± 0.01	0.20 ± 0.04	0.51 ± 0.23	ns
C20:4 n-6	4.11 ± 0.12	4.30 ± 0.30	4.13 ± 0.37	3.00 ± 0.19	3.16 ± 0.12	2.12 ± 0.13	3.20 ± 0.13	2.49 ± 0.20	3.30 ± 0.34	**b
C22:4 n-6	0.10 ± 0.04	0.19 ± 0.02	0.05 ± 0.01	1.41 ± 0.31	0.31 ± 0.07	0.94 ± 0.29	0.52 ± 0.11	0.45 ± 0.04	0.39 ± 0.14	**a
Total PUFA n-6	17.98 ± 0.96	19.00 ± 0.85	17.56 ± 0.47	20.49 ± 1.26	16.29 ± 0.64	19.36 ± 0.92	14.55 ± 0.22	19.09 ± 0.38	15.71 ± 0.61	**a
C18:3 n-3	3.82 ± 1.00	2.25 ± 0.22	1.76 ± 0.13	1.91 ± 0.15	1.74 ± 0.11	1.74 ± 0.04	1.81 ± 0.22	3.20 ± 0.37	4.13 ± 0.18	*ab
C20:5 n-3 (EPA)	3.75 ± 0.33	4.46 ± 0.34	4.16 ± 0.36	4.95 ± 0.24	5.37 ± 0.18	5.24 ± 0.26	7.45 ± 0.17	6.75 ± 0.14	7.26 ± 0.12	**b
C22:5 n-3	0.27 ± 0.02	0.38 ± 0.03	0.12 ± 0.07	0.69 ± 0.27	1.64 ± 0.09	0.63 ± 0.04	0.90 ± 0.13	0.71 ± 0.04	0.82 ± 0.33	*b
C22:6 n-3 (DHA)	11.40 ± 0.43	14.49 ± 0.29	16.95 ± 1.42	16.51 ± 0.76	19.93 ± 1.33	20.48 ± 0.66	22.80 ± 0.63	18.49 ± 0.17	21.68 ± 0.80	**b
Total PUFA n-3	19.24 ± 0.98	21.58 ± 0.61	22.99 ± 1.56	24.06 ± 0.67	28.68 ± 1.52	28.09 ± 0.89	32.96 ± 0.47	29.15 ± 0.49	33.89 ± 0.94	***b
Total PUFA	37.22 ± 0.14	40.58 ± 0.44	40.55 ± 1.19	44.55 ± 1.12	44.97 ± 1.22	47.45 ± 0.80	47.51 ± 0.36	48.24 ± 0.56	49.60 ± 0.92	**ab
n-3/PUFA	0.52 ± 0.02	0.53 ± 0.02	0.57 ± 0.02	0.54 ± 0.02	0.64 ± 0.02	0.59 ± 0.02	0.69 ± 0.01	0.60 ± 0.01	0.68 ± 0.01	***ab
n-3/n-6	1.06 ± 0.11	1.12 ± 0.09	1.31 ± 0.13	1.17 ± 0.09	1.76 ± 0.15	1.45 ± 010	2.27 ± 0.06	1.53 ± 0.04	2.16 ± 0.13	**b

decrease in the same samples was observed at day 60 and this correlates positively with the n-3/n-6 ratio of diets.

DISCUSSION

After an 8-week exposure of *Seriola dumerili* to the two experimental diets tested, diet has a strong effect on muscle lipid and fatty acid profiles during the refining period. The effect of diets is expected as the fatty acid composition of fish tissues usually tends to reflect those of dietary lipids (Bell *et al*., 2001; Jobling, 2001).

The lipids of the muscle from *Seriola dumerili* examined in the present study consisted mainly of polyunsaturated fatty acids (PUFA). The n-3 FAs and n-6 FAs are two biochemical families within the PUFAs, and they also have different biological effects (James and Cleland, 1996). Traditionally, fish with high fat content, like greater amberjack, have been considered to be nutritional important species since they have a relatively high content of n-3 FAs. However, it has been demonstrated that there is an inverse relationship between amount of n-3 FAs and total fat content (Kristinsson and Rasco, 2000). This implies that it is important from the nutritional point of view to focus interest upon getting species with high proportions of n-3 FAs instead of only insisting on the fat content. Previous studies have also demonstrated a beneficial role of bold fish, as well as fatty fish consumption, in the prevention of cardiovascular diseases (Colquhoun, 2001).

As cited previously, our analyses demonstrated that dietary lipid levels influences the lipid content including the FA composition in muscle as suggested by several authors in different fish species. Miller et *al*. (2005) demonstrated, in red snapper *Lutjanus campechanus*, a significantly greater amount of body fat deposition in fish given a ration containing 14% dietary lipid compared to other groups given a diet containing 8-10% dietary lipid. And Kucska et *al*. (2006) showed that the total lipid content of the cultured pike, *Esox lucius*, fed exclusively pellet containing 21% lipid, was also higher than fish fed prey-fish.

SFA were maintained almost stable. The differences were statistically significant along the experience ($p < 0.05$), but not between the two diets tested. Similar results for carp were found by Guler *et al*. 2008 the amount ranging from 26.6 to 29.6% of total FAs. In general, fish have relatively low levels in SFA, except for some species (Ackman 1989). Calado *et al*. (2005) showed that SFA determined in *Lysmata seticaudata* were not affected by dietary lipid since they were maintained between 24% and 23% of total fatty acids. Palmitic acid (C16: 0) was found as the predominant saturated fatty acid. The ratio values of C16: 0 / SFA were similar for the two types of food.

In our study, the decrease of MUFA percentage from initial to final samples was in favour of an other fatty acid class. In farmed *Sparus aurata,* Mnari et *al*. (2007) found a MUFA level ranging from 28.11 ± 1.11 to 31.17 ± 0.83% of total fatty acids which is near to our levels, and these results were obtained in Tunisia, so under the same environmental conditions. The high level of oleic, palmitoleic and arachidonic acid had been reported as a characteristic property of fish oils (Guler *et al*., 2008).

Hence, in reared *Seriola dumerili*, PUFA were the dominant group of fatty acids. When fatty acids were investigated, it was observed that the PUFA content was higher while that of saturated and MUFA was lower in farmed *Seriola dumerili*. Our results are similar to those reported in 11 species of queensland fish (Australia) (Belling *et al*. 1997), those authors found that PUFA reached 42.3% of total fatty acids.

In marine fish, the PUFA comprise mainly the n-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Ackman, 1989). However, the ratio of DHA versus EPA varies among species or among individuals. Thus, fish species with a high content of n-3 FA in the muscle is not necessarily a good source of DHA. In the present study, we observed that DHA and EPA accounted for about 30% of the total fatty acids in the muscle of *Seriola dumerili* (Tab. IV). The bony species contained almost four times as much EPA as the cartilaginous species (Hege *et al*., 2005). DHA accounted alone for about 11-30% of total fat content, which is considered to be particularly high. However, such high ratio of DHA has previously been demonstrated in the muscle of the tuna *Euthynnus (Katsuwonus) pelamis* (Saito *et al*., 1997).

A low level of C18:2 n-6 in 25% fat diet lowered the n-6 PUFA in the muscle. Furthermore, marine finfish species exhibit limited or no ability to desaturate and elongate 18:3 n-3 to n-3 PUFA and sometimes EPA to DHA as well as 18:2 n-6 to 20:4 n-6 due to low or absent $\Delta 6$ and $\Delta 5$ desaturase activities (Montero *et al*., 2004; Isquierdo *et al*., 2005). Other researchers have also observed similar results when studying the effect of four experimental diets on fatty acids composition of white seabass *Atractoscion nobilis* (Huang *et al*., 2007).

Bowman and Rand (1980) reported that AA is a precursor for prostaglandin and thromboxane, which will influence blood clot formation and its attachment to the endothelial tissue during wound healing. Apart from that, the acid also plays a role in growth. In our study, the greater amberjack have higher content of AA with the rich diet along the study, although at day 15 the AA was higher (4.30 ± 0.30%) for the first diet (17%) and 4.13 ± 0.37% for the 25% diet. Similar results were found in carp *Cyprinus carpio* and the AA content has been reported in a range of 4.38% of total FAs (Guler *et al*., 2008).

The n-3/n-6 ratio has been suggested to be a useful indi-

cator for comparing the relative nutritional values of fish oils (Piggot and Tucker, 1990). An increase in the human dietary n-3/n-6 fatty acid ratio is essential in the diet to prevent coronary heart disease by reducing plasma lipids and to reduce cancer risk (Kinsella *et al*., 1990). The increase in the dietary n-3/n-6 fatty acid ratio in favour of n-3 fatty acids also seems to be effective in preventing shock syndrome and cardiomyopathy (Bell *et al*., 1991). In this study, there is a refining period of 45 days, which is enough to obtain an adequate n-3/n-6 ratio. Given the ratio of 2.27, found in refined *Seriola dumerili* reaching the optimal for nutritional purpose (Simopoulos *et al*., 1989) is particularly due to n-3 FAs consisting mainly of EPA and DHA.

CONCLUSION

This study has shown that *Seriola dumerili* is a desirable item in the human diet in Tunisia when the levels of EPA, DHA and n-3/n-6 ratio are considered. This condition can be regarded as an explanation for the fact that the greater amberjack is richer in n-3 fatty acids when reared with a diet like the 25% fat diet tested, taking into consideration the fatty acid profile of the flesh. As a consequence, when human health is taken into account, Tunisian *Seriola dumerili* appears to be quite nutritious in terms of fatty acid composition and ratio.

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